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SOVIET COMPUTERS AND CYBERNETICS: SHORTCOMINGS AND MILITARY APP--ETC(U)

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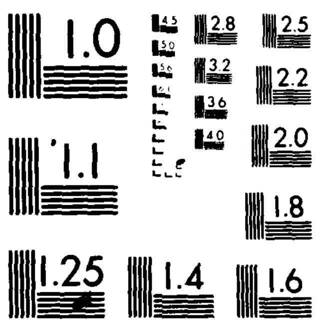

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STUDENT RESEARCH REPORT

SOVIET COMPUTERS AND CYBERNETICS: SHORTCOMINGS AND MILITARY APPLICATIONS

CPT MARK C. GILBERT

1980

GARMISCH, GERMANY

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CAPTAIN MARK C. GILBERT

June 1980

US Army Russian Institute

Garmisch, Germany

2825

DEPARTMENT OF THE ARMY
U.S. ARMY RUSSIAN INSTITUTE
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F O R E W O R D

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John G. Canyock

JOHN G. CANYOCK
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SUMMARY

In this paper the author traces the development of the Soviet computer industry along with its problems and shortcomings as discussed in the Soviet press. The major shortcomings noted tend to concentrate on organizational matters as opposed to hardware production. Nevertheless, the paper shows that a technology gap exists. A discussion of Soviet military applications of computers and cybernetics is presented to demonstrate the interests of the USSR in this field. The author concludes that the Soviets have so far been ineffectual in dealing with many of their problems. He also concludes that the Soviets have abandoned independent development and resigned themselves to following the US lead in order to close the gap.

TABLE OF CONTENTS

INTRODUCTION

Military scientific technological competition between the Soviet Union and the United States grew more intense during the Second World War with the development of the atomic bomb. It is a generally accepted concept in the writings of current strategic analysts that the United States enjoys an advantage over its Soviet adversaries in the field of science and technology. This belief has endured, notwithstanding several notable achievements by the Soviets in the fields of space exploration which have alarmed some Western analysts. America's scientific and technological advantages are integral elements in the delicate world balance today. In 1975 Dr. Malcolm R. Currie, the Director for Defense Research and Engineering said:

> American security, like American economy, stands on a foundation of technological superiority. We need superiority in defense technology. First, because the openness of our society tells our adversaries what we are planning in military technology while their secrecy forces us to provide for many possibilities. Second, in military operations we traditionally depend on superior quality to compensate for inferior numbers.[1]

Therefore the ever changing nature of military science and technology must be recognized and the balance of technology constantly reassessed to insure that the gap is not closed. Overwhelming technological superiority can no longer be taken for granted. This is true partially because the Soviet Union has not resigned itself to the status quo. Also quality can compensate for inferior quantity only up to a point, where superior numbers take over.

A major element in the military scientific technological competition between the United States and the Soviet Union in which quality is at a premium has been the field of computers and cybernetics. Computers and cybernetics are integral to a multitude of military systems, such as missile guidance systems, communications networks, antiballistic missile systems, and command control systems. Computers and cybernetics are essential instruments in other areas affecting military capability. These areas include information storage and retrieval, intelligence collection, processing and dissemination, and speeding the process of military research and development procedures.

As a result of the numerous and significant military applications of computers and cybernetics, the transfer of technology in this field from the United States to the Soviet Union is closely controlled. Whereas some computers have been exported from the US to the Soviet Union, such sales are closely scrutinized to prevent a significant transfer of technology which could threaten national security.[2] The majority of computers in use in the Soviet Union are products of their own indigenous industry and cooperative production plans within the Eastern bloc nations. In 1976 the installed base of computers in the Soviet Union was in excess of 25,000 and annual production exceeded 5,000 systems.[3] Because of the growth of the Soviet computer and cybernetic industry and its seemingly limitless capability for military application it must be considered as essential element for assessment of the military technological balance.

The major obstacle encountered in researching a topic of this nature is the tendency toward secrecy on the part of the Soviets in dealing with anything relating to military technology. As a result it is necessary to draw parallels

from the civilian sector of Soviet industry, an area about which they speak more openly. In doing this one must keep in mind that, in the Soviet Union, the level of military technology is generally higher than civilian technology. This assessment is qualified, however, in the following ways:

> Firstly, it cannot be said that the level of Soviet military technology is as high as the most advanced foreign technology...Secondly, a distinction can be drawn between military and civilian technology insofar as the former is specifically designed for use in war. There is, nevertheless, a considerable overlap between the two, and the distinction grows more blurred the closer one moves to the research end of the research-production cycle.[4]

The purpose of this paper is to examine the development of Soviet cybernetic devices (computers) and techniques and their shortcomings as described in the Soviet press. This is followed by a brief discussion of the actual military application of computers and cybernetics in the Soviet armed forces, and describes how and where such devices are used. Finally, the paper deals with the technology transfer issue.

INITIAL SOVIET DEVELOPMENTS

The development of computer science in the Soviet Union started at approximately the same time as it did in the United States. One of the very first machines for solving differential equations was designed and produced by the Soviet Academy of Sciences in 1941. However, Soviet development in this field has lagged behind that of the United States.

Computer systems are divided into two basic classifications, digital and analog. The differences between these two systems is the manner in which they perform their actions. Analog computers are continuous action systems, whereas digital computers are discrete action systems. Of these two, digital computers are the more complex and reliable systems and also require a higher degree of technological ability for their development and production. It is in this field that the Soviet development has been slower than that of the West. Whereas United States technological development in the computer industry has passed through four relatively distinct phases of production, the Soviets have only succeeded in developing third generation computers. Each of the four Western generations lasted between five and eight years while the three Soviet generations can be roughly related to decades with the first generation extending through the 1950's, the second generation occuring in the 1960's, and the third generation extending to the present. These generations are universally described to coincide with the progress of the United States computer industry as it has been the leader in the field since the early developments in computer production. A Soviet scientist writing near the end of the second generation of Soviet computers and looking forward to the third described the first three generations as follows:

a) the first generation, utilizing vacuum tubes as basic elements (now a thing of the past).
b) the second generation, utilizing small scale semiconductor and finite circuit elements. These machines, possessing greater reliability, higher speed and compactness,are now (1967) the most widely utilized.
c) the third generation, using highly reliable micro-miniature integrated circuits with low power consumption. This type of digital computer will be the primary type used in the near future and will undoubtedly surpass its predecessors.[5]

This scientist's prediction of what the next generation of Soviet computers would consist of was by no means clairvoyant, as he had Western development as his model, already well into third generation computers at the time.

General direction of the Soviet computer industry, like direction of all other major industries, comes from the state five year plan. Computer design is accomplished by one of two different types of organizations. The first of these consists of design bureaus of the computer manufacturing plants in the Soviet Union which are regulated by the Ministry of Instrument Construction, Means of Automation and Control Systems, along with the Ministry of Radio Industry. Computers designed by plant design bureaus tend to be specialized and more widely distributed and used throughout the general economy. The second type of organization is made up of independent scientific and research institutes which recieve their direction from the Academies of Science of the Soviet Union and the individual republics.[6] Computers designed by these research institutes are generally more technologically advanced. Rarely will a computer production plant with its own design bureau be called upon to manufacture a

machine designed by one of the research institutes. This is indicative of the fact that there seems to be little cooperation between the two different methods of design in the Soviet computer industry.

SOVIET PROGRESS INTO SECOND GENERATION COMPUTERS

The Soviet computer industry was very slow to gain momentum. Introduction of the BESM-6 in 1957 marked the Soviet Union's entry into the second generation of computer development but the trend did not carry over into related fields. Expected improvements in peripheral devices did not come about and many major shortcomings in computer development remained unsolved.

It was not until the 1970's that the Soviet Union realized the dangerous potential of the gap between its own and the United States' computer technology and began to afford it the necessary attention and priorities. The directives of the 24th Party Congress called for large-scale increases in computer production to take place during the ninth five-year plan (1971-1975). The planned production of computers was to increase by a factor of 2.6. In his address to the Party Congress Secretary Brezhnev stated that "in the coming five-year plan, special importance...is attached to the organization of expanded output of modern computers."[7] In this address Secretary Brezhnev set the tone for high echelon Party and government leaders to display strong interest in computer technology and applications. Such high level interest was not apparent previously. Not only did the 24th Party Congress show new interest and emphasis on computer technology but it also was much more specific in its goals than the 23rd Party Congress had been. One of these goals was the development of a "state-wide system...for the collection and processing of information for accounting, planning and management of the national economy based on a state system of computer centers..." Commenting on this proposal, Academician N. Fedorenko, the Director of the Soviet Union's Academy of Sciences, stated that such a system was necessary to insure "significant increases in the efficiency of the utilization of computers...and qualified personnel."[8]

A significant result of the ninth five-year plan was that the Soviet Union entered into an agreement with Poland, Czechoslovakia, Hungary, Bulgaria and the German Democratic Republic to design and produce a series of program-compatible general purpose computers. The major motives of this were to take advantage of the high technological ability of some of the satellite nations, such as East Germany, and at the same time provide for centralized control, thus eliminating any duplication of effort.

Along with the development of technology it is necessary to look at the emerging problems and shortcomings of the Soviet cybernetic and computer industry. In order to examine the treatment of systemic shortcomings in the Soviet press, several different approaches are possible. The method to be applied in this paper is chronological in approach. By attacking the problem in this manner it is easier to track problems along with developments, and trends of recurring problems may become more apparent. The frequency of any particular shortcoming may be a good indicator of its criticality.

One of the first major criticisms of the Soviet computer industry came in 1964 on the pages of Izvestiya. In this article the computer industry was criticized for a lack of centralized direction. It was pointed out that computers deserved more attention at higher levels, and it was proposed that the "responsibility for the development of work in the field of computer technology and its application...be assigned to a deputy to the Chairman of the Council of Ministers of the USSR."[9] An article in Pravda in 1966 reiterated the need for centralized management of the computer industry, but went beyond this idea to bring out some specific shortcomings in the production and inculcation of computers into the economy. This article asked the question "as to whether [Soviet]

industry is ready to meet the requirements of the national economy for computers." The author answered this question by saying, "Unfortunately, we must state the situation is far from optimistic." Another problem cited was the lag in development and manufacture of peripheral components. The article stated that an "underestimation of the use of computers" is responsible for the "gap between the electronic brain and its peripheral equipment."[10]

The recurring theme of lack of centralized direction was again brought up in an article by V. Glushkov in 1966 which stated that the reason for the delay in adoption of computers in industry "lies in inadequate coordination of operations." The problem of peripheral devices was again addressed and the major problem of a lack of software was addressed for the first time. In addressing these problems he stated that even though the processors operate reliably, "the external devices break down more often--practically every day." On the subject of computer software he wrote that "this work in our country has been really unorganized."[11]

The need for centralized control was again well argued in 1967 following the monumental declarations of the 23rd Party Congress. The problem had led to a lack of centralized guidance, incompatibility of machines, and duplication of effort.[12]

The software problem was also addressed in Pravda. A newly emerging problem was mentioned in the same article concerned servicing of equipment. Users were responsible for their own maintenance but incapable of performing such service properly. The author advocated adoption of the Western practice of maintenance services being performed by the manufacturer.[13]

Inefficient utilization of computers was another cause for criticism in the Soviet Union. Computers were more often than not utilized at less than half of their capacity. This was attributed to a number of reasons. One interesting accusation is that plant managers wanted to possess computers as a status symbol but once they had them they did not particularly want to use them. Another cause of this problem was the economic system of the Soviet Union which does not permit a delay in plan fulfillment while attempting to assimilate new technology. Yet another reason was the lack of qualified personnel to operate the machines. Probably the most important reason cited for this lack of efficiency is the fact that although many organizations have a need of a computer, they don't need the entire capacity of the machine all to themselves. As a result the lack of computer centers patterned after time-sharing techniques of the West is a major contributing factor to Soviet computer inefficiency. In addition, a psychological problem is discussed. Personnel are accused of refusing to accept the "significance of computer technology in the future development of the national economy and science."[14] This 1968 article seemed to offer a warning to all leaders and managers, including military officers, that computers and cybernetics constitute the wave of the future, and those who refuse to identify with the new trend may be in danger of being left behind. The by now familiar themes of lack of centralized control, lack of adequate software and poor quality of peripheral devices were also present in this article.

In January 1969 Lieutenant General A. Fomichev, (equivalent to a US Major General), an armor officer then serving as First Deputy to the Commander of the Transbaykal Military District, published an article about problems encountered in computerized military teaching machines. The potential for broad-scale implementation of these devices was described as "very limited". The major problems cited included a lack of repair parts and greatly limited capability of the machines. The general stated that "the primary problems are the development of teaching machines with a wide range of capabilities and the development of standard

programs for them."[15]

As a consequence of the 1968 All-Union Conference on Computer Programming, Academician V. Glushkov, Director of Cybernetics of the Ukranian Academy of Sciences, published an article concerning the lack of qualified computer personnel with emphasis on programmers. While praising an overall increase in computer specialists he stressed that a "lack of qualified computer personnel with a knowledge of systems analysis and systems programming continues to be felt." This problem was exacerbated by a shortage of qualified instructors. Those qualified to instruct were employed elsewhere in developing new systems or performing scientific research. In order to help alleviate this problem he called for using people from industry or the military with experience in the field. The shortage was such that Glushkov even advocated using people without degrees, "requiring only that they have a good theoretical and practical knowledge of the subject."[16] This proposal by Glushkov serves to demonstrate just how serious this lack of qualified instructors really was. Whereas people drawn from the military and industry logically may be assumed to possess a practical knowledge of systems analysis and systems programming, at least on a limited basis relating to their experience, those not holding a degree would most probably not have the required theoretical background. If the institution is intended to produce a degree, the logical question arises as to how this can be accomplished when the instructors have not themselves attained that level of competence.

SOVIET PROGRESS INTO THIRD GENERATION COMPUTERS

A result of the 24th Party Congress, although not publicized, seems to have been a decision to abandon attempts at development of an independent third generation Soviet computer design and follow the lead of the already successful and more advanced United States computers. This is evidenced by the resultant system series of the East European design and production agreement, the "Ryad Series" computers. The introduction of this series in the Spring of 1972 marked the arrival of the Soviet computer industry into the third generation of computer technological development. This system seems to have been modeled after the highly successful IBM 360 series, a third generation United States system. The designations of the computers in the Ryad Series follow a standard numbering series beginning with ES[17] followed by a four digit identifier. Computer systems are designated with identifiers 1010 to 1060 with the corresponding processer units numbered 2010 to 2060. The characteristics of the Ryad processor units are roughly equivalent to the processor units of the IBM Series having the same last two digits. In evidence of this fact, Control Data Corporation purchased an ES 1040 in 1975. A series of user programs designed for the IBM 360-40 were loaded with no modifications whatsoever and they ran perfectly.[18]

This Ryad series numbers seven different computer systems. Each of the six countries involved in the agreement have the responsibility for developing at least one processor unit. A brief description of the computer systems and the countries responsible for the processor units follows:[19]

ES 1010 computer--The ES 2010 processor unit is produced in Hungary. The ES 1010 is the smallest intended for limited size scientific and technical calculations for processing accumulated measurement data; for small process control systems; and for teaching systems. It is capable of performing 10,000 operations per second. The ES 1010 has been mounted in a mobile van for on-site operations, thus increasing its potential for military applications.

ES 1020 computer--The ES 2020 processor unit is produced in the Soviet Union and Bulgaria. The ES 1020 has been described both as a small and a medium productivity computer. It is intended for scientific and technical, economics, management and special tasks; for small control systems; and for teaching systems. The 1020 can be incorporated into multi-machine systems as well as operation in an autonomous mode. The 1020 is capable of performing 20,000 operations per second.

ES 1021 computer--the ES 2021 processor unit is produced in Czechoslovakia. The ES 1021 is sometimes referred to as the ES 1020A, and is a specialized medium productivity unit oriented towards single-processor and single-program operation. It is to be used for economics, scientific and technical, and data processing problems with an orientation towards small management systems. The ES 1021 is capable of performing 40,000 operations per second.

ES 1030 computer--The ES 2030 processor unit is produced in the Soviet Union and Poland. The ES 1030 is a medium productivity unit intended for scientific and technical, planning and economics, and data processing operations. It can operate in a multi-processor system and is capable of 100,000 operations per second.

ES 1040 computer--The ES 2040 processor unit is produced in the German Democratic Republic. The ES 1040 is the largest computer in the series to be manufactured exclusively outside of the Soviet Union. It is a medium productivity

system designed for scientific technical computations, economics, and data processing. The ES 1040 is capable of 300,000 operations per second.

ES 1050 computer--The ES 2050 processor unit is produced in the Soviet Union. The ES 1050 is a high productivity machine intended for scientific technical computations, economics work, for use in large computer centers, in large-scale data processing systems, and in multimachine complexes. The ES 1050 is capable of 1,500,000 operations per second.

ES 1060 computer--The ES 2060 processor unit is produced in the Soviet Union. The ES 1060 is the largest of the ES systems. It is a high productivity system intended for basically the same type operation as the ES 1050. The ES 1060 is capable of approximately 2,000,000 operations per second.

An excellent article pertaining to the software crisis in the Soviet computer industry appeared in Izvestiya in 1970.[20] The author was V. Belyakov, an administrator of the computer center of the USSR Academy of Sciences. Belyakov flatly stated that software development in the Soviet Union remained in a "primitive stage," and blamed this largely on the lack of trained personnel. He further asserted that "the situation with respect to training personnel is very grave. Today [1970], the output of specialists in this field from higher educational institutions of the USSR does not satisfy the existing demand, and this demand is growing rapidly." Belyakov also attributed part of the problem to piecemeal programming techniques whereby programs are developed by "uncoordinated groups of ten to fifteen persons" working for different agencies with no one actually in charge. One final contributing factor to the software crisis cited by Belyakov was the simple fact that not enough attention or funding is dedicated to software development. The pursuit of sophisticated hardware, while neglecting the concurrent development of an adequate software package, resulted in widespread inefficiency. The problem was compounded by the fact that allocated funds which were insufficient to begin with were then insufficiently utilized. Along with proposing the obvious increase in fund allocation for software development, he also prescribed the concentration of equipment in large computer centers as a partial remedy for the software problem. In this way the best software experts could also be concentrated. Belyakov's proposal would help alleviate the problem of inefficient utilization of computers by establishing centers which could be used for time sharing. Western experience, however, has demonstrated that the best way to develop software packages is to develop them concurrently with hardware.

In 1969, Pravda ran a series of articles entitled "Letters from the Ministry." In the final article of the series comments from the Ministry of Machine Construction and Instrument Industry revealed part of the psychological problem then existent in the Soviet Union. Workers were pictured as extremely reluctant to discard old work methods made obsolete by the computer. Examples of duplication of computer effotts by manual means were cited. The problem was compounded by the fact that high-level administrators required written reports on production plan fulfillment, statistics that were available through the computer.[21] Other potential obstacles not specifically mentioned in this series, but worthy of consideration include displacement of the work force and productivity loss due to the need for large scale retraining programs.

The high level interest in development of computer technology which emerged with the 24th Party Congress and the ninth five-year plan (1971-1975) did not produce any reduction of industry criticism in the Soviet press. The criticism persisted and in some ways became more insightful. A sharp criticism of the computer industry appeared in Pravda in 1971. Candidate of technical sciences,

B. Del Rio, commented candidly about the gross lack of standardization in the Soviet computer industry.[22] In her article she noted that some computers were delivered with a fewer number of memory blocks than the original design called for.[23] An appropriate metaphor was utilized describing a customer who ordered a six-cylinder automobile but received one with only two. The problem of peripheral devices was again attacked with specific emphasis on the lack of adequate input devices. An enlightening insight was provided concerning problems with the proposed state-wide computer network. The lack of standardization was singled out as the most important factor in holding back this project at that time (1971). In discussing the software problem, Del Rio for the first time cited the consequences of insufficient software development. In writing of this she stated that "because of this [the lack of software development], as a rule an enterprise that receives a computer will not be able to use it to full capacity for two years or more [after reception]."

The lack of trained personnel cannot be better illustrated than by an Izvestiya article which also dealt with the psychological problem of "distrust of the new technology".[24] The article is a criticism of a plant in Tomsk for the manufacture of manometers (instruments for measuring gas pressure) and equipped with a Minsk-22 computer. The article stated that the programming section consisted of seventeen people, not one of whom had any specialized training. The programmers were graduates of mathematical or pedagogical institutes but ahd absolutely no experience or training in computers.

Even when the announcement of the Ryad Unified Computer System was made in January 1972, it was accompanied with a list of inadequancies and other indicators of problems in the industry. The announcement in Pravda of the first of the series, the Ryad 1020, was accompanied by the question "will the Ryad 1020 be able to utilize its immense capabilities with a maximum return?" The reply offered to this question is a less-than-optimistic "It is difficult to say."[25] Pravda's delineation of the problems runs along familiar lines. Of special note is the fact that just after the announcement of the ES 1020 the All-Union Conference on the Application of Computer Technology and Automated Control Systems in Enterprises and Branches of Industry was convened in Moscow. In a series of articles leading up to this conference, the then First Deputy Chairman of the State Committee on Science and Technology and the Chairman of the Conference Organization, D. G. Zhimerin, listed what he called the "many unresolved problems and inadequacies:"[26]

a) the work of ministries and agencies in introducing computer technology is poorly coordinated.
b) work on unifying already developed automated systems and providing for their interaction and compatibility is falling behind.
c) work on methodological questions concerned with control systems, their software and data provisioning has been inadequate.
d) there are no fully developed hardware systems as required for control applications.
e) despite the fact that adequate quantities of electronic machines are produced, their quality does not meet current needs, especially for major control systems.
f) communications systems are not adequate for the transmission of large volumes of data.
g) remote user terminals do not exist.
h) the number of qualified personnel working in the area of computer technology is insufficient and adequate steps have not been taken to provide more specialists.
i) fundamental work is required in the area of documentation and information organization.

j) existing computers are not equipped with technical software facilities for operating over communication networks.
k) success has not been achieved in requiring computer manufacturers to provide for installation, repair and software maintenance.
l) loading factors of installed machines are too low, since too many organizations with computers are not qualified to use them.
m) there are no generally accepted and enforced methods for evaluating economic efficiency of control systems.
n) the question of financing the development of control systems requires examination.

It appears that the Soviet computer industry was facing a multitude of difficulties as they entered the third generation of computer technology.

In August 1972 a letter appearing in Pravda criticized the Minsk Ordzhonikidze Computer Plant for poor quality in the Minsk-32 (a second generation machine) support package.[27] To answer the accusations, the plant's chief engineer, I. K. Rostovtsev, was consulted. Rostovtsev called the letter "a lie--the Minsk-32 computer has the best software compared to other computers." But when asked if the software was designed to meet the needs of the users he replied, "Well, that is another matter." The article pointed out that the lack of programs had caused the Minsk-32 computers to be operated with programs designed for the smaller Minsk-22 computer.

The problem of training specialists was also addressed:

> The USSR Ministry of Higher and Secondary Specialized Education cannot cope with the compilation of educational plans for the appropriate departments. Students at the Belorussian University and the Minsk Radio Engineering Institute are being trained on a Minsk-22 computer which has already become obsolete. They are not being acquainted with the Minsk-32 or with the latest computers, such as the ES-1020.[28]

A rare bit of statistical evidence of another problem of the Soviet computer industry, low productivity, was given in the journal Pribory i sistemy upravleniya (Instruments and Control Systems) in 1972.[29] Pessimistic predictions for production of special purpose machines during the 1971-1975 five-year plan foretold that the industry would only be able to fulfill 40 percent of the country's requirements. The prediction was fairly accurate as 37 percent of the requirements were fulfilled.[30] This shortfall was not as serious as it may at first appear. It can be explained, at least partially, by the fact that the Soviets were beginning at that time to follow the lead of the West to move toward the production of general purpose machines. More of the industries' efforts were also being diverted to development of the Ryad Series.

Again addressing the problem of software, V. Galeyev, the Laboratory Chief, Main Scientific Research Computer Center, told of the gross inefficiency in maintaining program libraries.[31] He cited the Computer Center of the USSR Academy of Sciences as an example, where during a check of the library, it was found that out of approximately 2000 programs designed for construction engineering computations, only 123 were functional.

The lack of standardization and coordination of effort was again the target of V. Glushkov in 1973.[32] He stated that "examples of related industries pooling their efforts in the development of standard system designs based on maximum unification and standardization are...an exception rather than the rule."

RECENT DEVELOPMENTS

P. S. Pleshakov, the Soviet Minister of the Radio Industry, wrote in 1978 of further progress and projected developments in the digital computer industry.[33] Stating that the first stage of the Unified System of computers has been completed, he described a program for a second stage of hardware production (Ryad-2) which includes not only additional processing units, but over 30 new types of peripheral equipment as well. The article went on to state that plans exist for further development of the Ryad-2 system into a Ryad-3 computer system which will be designed primarily for use with special processors and in multi-system networks. Pleshakov also stated that work was in the initial stages for super high-efficiency multiprocessor systems which will be capable of upwards of 100 million operations per second.

The problems of centralized management and servicing were also addressed. Steps have been taken to attempt to alleviate these problems. Pleshakov stated that "an All-Union association has been established to provide for comprehensive centralized servicing...[but] even though the association has experienced fast growth, it can not yet serve the growing demands of users, especially maintenance of computers, programming, and training of specialists."[34] He also stated that a coordinating committee for the development and introduction of new systems has been established. This committee consists of the first deputy ministers of several ministries. Which ministries are included was not specified. This council has not met with complete success, either.[35]

The problem of peripheral devices was addressed again in an editorial published in Pravda in December 1978.[36] The article dealt specifically with sensing devices (input elements). It stated that "...sensing elements are not included in the sets of computer hardware and automated management and control systems that have been developed in the [USSR].[37] The article went on to state that the Soviet computer industry must undergo large-scale changes in order to alleviate this problem which the authors considered quite serious. They held little hope that immediate corrective action would be taken, however, and pessimistically stated, "All this will be difficult to achieve without the help of specialists, and as yet no one is training such specialists...The country still does not have a single specialized learned council where a person seeking to obtain a candidate's or a doctor's degree can present a dissertation in this field..."[38]

A book review by N. I. Cheshenko, the Deputy Head of the Chief Administration for Computer Technology and Control Systems of the USSR Council of Ministers' State Committee for Science and Technology, was published in the journal Ekonomika i organizatsiya promyshlennogo proizvodstva (Economics and Organization of Industrial Production) in August 1978.[39] The book reviewed was written by Yu. P. Lashin and entitled Razvitiye avtomatizirovannykh sistem upravleniya v promyshlennosti (The Development of Automated Management Systems in Industry) and was published in 1977 by the Ekonomika Publishing House in Moscow. Lashin's book is one of the first to offer evidence that Soviets are making some progress in addressing problems in administering the introduction of computer systems. It demonstrated how the emphasis in computer use has changed during the eighth, ninth and tenth five-year plans. The percentage of investment in computerization in non-production branches has steadily grown. An analysis of expenditure differences between the ninth and tenth five-year plans for computers demonstrates a move toward solution of the problems of software development and maintenance. Percentage of expenditures rose from 10 to 20 percent for software development and from 30 to 32 percent for operating and maintenance costs, while percentage of expenditures for hardware reduced from 60 to 48 percent. "The ninth five-year plan stressed

merely the number of automated management systems. The tenth calls for attaining greater efficiency...by concentrating computer capacity and organizing computer service for large numbers of clients."[40]

The problem of misutilization of computers was again highlighted in an article by A. Myagi, the Director of the Computer Center of the Ministry of Light Industry of the Estonian Republic in March 1979.[41] He complained that a large number of computers in the Soviet Union are under-utilized according to the norms established by the Central Statistical Administration and offered computers in the Estonian Republic as an example. There the average daily utilization was stated as nine hours for all computers. Daily utilization of Ryad series computers was quoted as seven hours as compared to a norm of 15 hours. Myagi recognized efforts to organize computers into time sharing centers as helping to partially alleviate this problem, but at the same time called for the creation of incentives in the form of "economic stimulation funds" to help bolster computer efficiency and effectiveness.

The need for centralized management was once again addressed by V. Myasnikov, the Director of the Chief Administration for Computer Equipment and Control Systems of the USSR State Committee for Science and Technology, in April 1979.[42]

Myasnikov pointed out that the existing lack of centralized management resulted in failures in "ensuring the timely and complete delivery of equipment." This problem was reemphasized in an editorial in Pravda in July 1979.[43] This editorial stated that information centers are suffering from a lack of equipment, especially microfilm and electrographic devices, and as a result only 10 of 89 branch information centers possessed automated systems at the time of writing.

An excellent summary of the existent shortcomings of the Soviet computer industry was contained in an interview with V. Glushkov, the recognized dean of Soviet cybernetics, in February 1979.[44] Glushkov cited four persistent problems. The first of these problems was a personnel problem. This combines both the critical shortage of trained personnel and the psychological problem of convincing key personnel of the utility of cybernetics. Even though the ninth five-year plan took great strides toward the creation of a foundation for extensive training of specialists in automated systems, the shortage of qualified instructors has been a major impediment.

The second shortcoming cited was equipment-related. Glushkov stated that, "Unfortunately, little attention is paid to automated management system hardware." Peripheral devices, especially communication lines, are where equipment shortcomings are concentrated. Glushkov reestablished the estimation of the lag between Soviet and United States computer technology at ten to fifteen years as the third problem. Early in the interview he stated that the shift to third generation computers did not take place until the "end of the ninth five-year plan." This was accomplished in the United States circa 1957. Later in the article Glushkov specifically stated, "the growth rate [for computers and cybernetic technology] in our country now [1979] is about the same as it was in the U.S. in 1960-1971."

The final difficulty cited by Glushkov was the organizational problem. "The problem is that the only way automated management systems can be efficiently introduced on a wide scale is by using standard designs for these systems... Unfortunately, standard designing has still not been widely adopted..."[45] Planning procedures also suffer from a lack of standardization thus causing duplication of effort. A centrally directed effort would be better equipped to

combat some of the bureaucratic roadblocks to automation. For example, Glushkov cited two specific instances. The installation of a computer center in an electronics plant in Lvov required the changing of management documents so that they could be used directly for input to the computer without having to be "translated". Some of the forms had to be approved by the Ministry of Finance, however, and, for some, approval was never obtained. The second example cited was similar as it again involved attempts at standardizing forms that were blocked. This instance arose from attempts to introduce an automated management system for Kiev's transport offices where departmental regulations provided the obstacle.

Despite the lag in Soviet digital computer technology, the USSR has not encountered a similar lag in their development of analog computers. Soviet technological development in this field is generally considered by Western analysts to be on a level with the West. As a result, the Soviets tend to compensate for their lag in digital technology with analog computers. Analog computers can never effectively replace digitals, however. Analogs are special purpose devices with greatly limited applications. They do not lend themselves to miniaturization as digital computers do. Digital computers as a result of their discrete actions, as opposed to analog computers' continuous actions, are faster, more precise, and more efficient. Many cases of this type of substitution are found in military applications, and thus, many systems which utilize digital machines in the West are equipped with analog devices in the Soviet Union. One such example is aircraft flight control computers. The Soviet Union does not seem satisfied with these substitutions, however, and displays a continual interest in converting these systems to digital machines whenever possible.

CYBERNETICS DEVELOPMENT

Another related area to be examined in this paper is the Soviet interest in cybernetic techniques. As was the case with digital computers, the Soviet development of cybernetic techniques closely follows trends in the United States. The Soviets define cybernetics as "the science of control of complex systems in man, machines and society."[46]

Like computer technology, the field of cybernetics was slow to develop in the Soviet Union. The theoretical base of cybernetic methods was repressed during the Stalin era and emerged only in the post-Stalinist period. Initially, advocates of cybernetics overly glorified the technique and offered it as a panacea for all that needed to be done in the military and the economy. Such inflated claims served to alienate some of the more senior military officers who tended to hold on to their traditional views and methods.[47] Based on their close relationship, cybernetic theory gained importance along with the drive for increased computer technology. Present Soviet writings on the utility of cybernetics in military applications demonstrate a widespread interest, but advocates of cybernetics present their arguments in a realistic manner never forgetting to keep in mind the predominance of the human factor in the final decision making. Another explanation of the increased interest in cybernetics in the USSR is the Soviet Union's fascination with anything scientific. This fascination was well defined by M. [illegible] Jones as follows:

> The Soviet press, including the military press, is replete with the universal exhortation to place everything 'on a more scientific bases'. One of the harshest criticisms that can be levied against a Soviet military officer is to accuse him of failing to display proper reverence for scientific advancements in weapons technology.[48]

All science in the Soviet Union must be reconciled with dialectic materialism, however. It was on this basis that Stalin repressed scientific developments on the grounds that they were not necessary. This stand in the USSR was softened in the mid 1950's with the emergence of Khrushchev.

SOVIET MILITARY APPLICATIONS

The Soviet view of the utility of computers and cybernetics in the military was well illustrated as early as 1968 in the following quote:

> Military commanders now rely on mathematics, computer technology, probability theory, modeling, game theory, etc. Network diagrams are also very useful in finding the optimum plans for training subunits for battle, in planning marches, in transporting equipment, in conducting tactical exercises, in range firing, etc.[49]

Military competition with the West is a major factor in the Soviet drive to incorporate this new technology into military affairs. Soviet military leaders watch developments in Western military organizations with a keen and envious eye. The application of computers as components of strategic weapons and intelligence gathering systems such as ICBM's and earth satellites is obvious. Coupled with this is the premise in Soviet military thought that future wars will be nuclear.[50] The nature of nuclear conflict and increased mobility brought on by mechanization have some noteworthy characteristics. The inherent shortened period of time for military activity, greatly increased scale of operations and rapidly changing situations necessitates the incorporation of computers and cybernetics in the control and decision-making process. In discussing the role of cybernetics in the military, Colonel G. Telyatnikov, a candidate of philosophical sciences, stated that "mathematical methods and electronic computer technology are powerful means of increasing the scientific character of leadership and preventing subjectivism....Without cybernetics, it is impossible to control the military forces."[51]

Open source references to Soviet military applications of computer technology are rare and when they do appear they are extremely general in nature. Infrequently articles appear in the Soviet press which mention computer technology specifically linked with weapons systems or exercises. In July 1968 mention was made of high-speed digital computers used in conjunction with a large-scale artillery exercise.[52] Unfortunately neither the systems used nor the organizational level at which they were employed was specified.

In 1970 an interesting disclosure of how computers are employed in river crossing operations was made. Data such as river depth and flow, weight and dimensions of tanks, vehicles, weapons and fording equipment, along with maximum loads are input into the computer. The computer then outputs the answers to such questions as when, how, and where the crossing should be made, and with what loads.[53] In this case the computer was identified as the M-220.[54] Computers are also being utilized by military engineers in the planning of military construction. Programs have been developed not only to aid in design and construction control, but also to control allocation and distribution of construction materials.[55]

A field in which computers are of noted utility is that of antiaircraft defenses. The increasingly short time available for target acquisition and destruction necessitates that the process be automated to as great a degree as feaible. The Soviets have applied computers to the algorithmization of radar information to guide antiaircraft weapons systems.[56]

Occasionally evidence of a machine with military applications emerges in the civil sector. Such is the case of the K-200 computer. Many of the K-200's

specifications lead to the conclusion that it was originally a military machine designed for airborne installation. Among the specifications that lead to this conclusion are the power frequency requirement (400Hz) and its dimensions. The 400 Hz is the most common power supply for use onboard aircraft. Its compactness (58 x 70 x 66 cm) suggests that it was designed for use in a confined space, such as onboard an aircraft. Other characteristics which evidence a military application for the K-200 include the fact that it requires no special air conditioning. Another interesting feature is that it comes with a complete software package, an unusual occurrence for a Soviet computer. This supports the conviction that it has been around for a longer time than is readily evident. Discussion of auditory analyzers (devices for converting sound such as voice commands into computer input) leads to further speculation that the military application may be in the field of space vehicles.[57]

One area in which the military application of computers is clearly evident is the field of training. In 1967, the Army Scientific Methods Conference on the Application of Hardware and Programmed Instruction was held. This conference concerned primarily self-testing equipment.[58] Besides testing, however, the Soviets apply computers in military training to teaching and simulation. Soviet interest in military teaching machines first appeared in 1961. The range of complexity of machines employed goes from simple teaching machines to complex digital computers. Major work in the field was initially accomplished in the Kiev Higher Engineering Radiotechnical School.[59]

It is insufficient to limit discussion solely to computer hardware. Soviet military leaders have shown a great deal of interest in applying cybernetic techniques along with computer hardware for the solving of military problems. Whereas sophisticated computer technology, because of its expense and requirement for highly trained personnel, tends to be found at higher organizational levels, cybernetic techniques can be implemented as low as platoon and squad level. The management process is enhanced by the employment of cybernetics for purposes of troop command and control, intelligence and processing, situtation modeling and decision making.

Three areas of cybernetic techniques which seem to have attracted the greatest deal of interest are queuing theory, network planning and game theory. The first of these, queuing theory, is more commonly referred to in Soviet writing as the "theory of mass servicing". The basic concept is to establish a relationship between service units, such as antiaircraft rounds, and the number of demands, such as attacking enemy aircraft, so that the system, the antiaircraft weapon, serves the demand in the most efficient manner. This technique is also very useful in solving military logistic problems.[60] Network planning, a sort of schematic diagramming to show sequence and interrelationship of tasks directed toward a common goal, is also utilized in solving logistic problems.[61] Game theory is employed to aid military decision makers by allowing them to test a number of varying ways to allocate their combat resources.[62]

One very interesting Soviet application of these cybernetic techniques is the attempt to operationalize the Soviet concept of "correlation of forces". Since such a great deal of Soviet strategic thinking is based on this concept, it stands to reason that planners would like to apply cybernetic techniques to optimize the military factor of the correlation of forces. This, of course, requires that quality judgements on personnel and weapons system effectiveness be quantified. This is as difficult a task for the Soviets as it is for Western decision makers, however.[63]

Soviet military theorists are also using cybernetics as a way of studying and testing new tactical concepts. It must be noted that the commitment of Soviet forces in actual combat between World War II and Afghanistan has been minimal. While on balance this is an admirable accomplishment, the possible deleterious effect of such long term inactivity on the military must be recognized. Military cybernetics provide a surrogate practice field for testing new tactics in the absence of any actual combat situations.[64] This is accomplished by simulation of tactical situations for testing outcomes of various courses of action. Extremely sueful in this respect is game theory.

Cybernetics are not restricted to aiding commanders in preparation for battle. Actually, the application of cybernetics which receives the greatest deal of attention from the Soviet military is battlefield decision making. The use of cybernetics in this field is lumped under the term "troop control" and the systems which range from very simple calculations to complex computer systems are identified in Soviet writings by the acronymn ASUV.[65] These systems combine four actions: information storage and retrieval, operational planning calculations, decision evaluation and transmission of commands.[66] The increased storage capacity and speed of retrieval of information greatly enhance decision-making efficiency. The time factor has gained a great deal of significance in troop control. It requires that a vast amount of information be readily available to the commander for consideration at a moments notice.[67] Operational planning calculations can take the form of one of three different types: direct, inverse, and optimizing. Direct calculations analyze a situation and a given plan. The output is a prediction of what the result will be. Inverse calculations, on the other hand, use the desired result of a plan for input and provide the required force structure to produce that result as output. Optimizing calculations combine these techniques to come up with the best plan of action with a set force to maximize destruction of the enemy while minimizing friendly casualties.[68] Decision evaluation is accomplished by direct operational planning calculations as discussed above. Transmission of commands merely involves the use of devices such as teletypes and radios in communications networks.

At higher levels of organization the calculations are further speeded by the use of computers. The lowest level at which computers are mentioned in the Soviet Armed Forces is the division. Computers are described as providing calculations for artillery fields of fire, evaluating relationships between forces and solving tactical planning problems.[69] An article appeared in Krasnaya zvezda in March 1979 stressing the utility of cybernetic techniques for determining the most effective use of weapons systems in battle and also in facilitating logistics operations.[70] The algorithms employed to solve those problems are the product of a joint effort of mathematicians, computer programmers and military commanders. V. S. Frolov, a Soviet expert on the subject of military applications of computers, enumerated some of the problems which can be solved with the aid of computers as follows:

a) processing incoming information, solving data processing and logic problems and the encoding and decoding of information.
b) evaluation of the effectiveness of armaments under actual combat conditions and the selection of more effective combat methods.
c) solution of (artillery) target acquisition problems.
d) production of decision-making data necessary to the commander.
e) processing data related to material and technical supply, storage accounting, and the disposition of material.
f) making combat readiness calculations.[71]

Frolov cautiously points out, however, that the human element cannot be ruled out by the use of military cybernetics. The commander still must make the final decision, and included in this decision are non-quantifiable factors, such as political and moral questions, which must also be considered.

In order to further determine what the Soviets consider as possible applications of military cybernetic devices and techniques, it is useful to look at which US applications are given the most attention in Soviet military writing. This interest ranges from massive systems like the National Military Command System to smaller tactical aids such as "TACFIRE", the field artillery fire direction aid. In larger systems, the greatest deal of attention is given to peripheral equipment and information collection and transmittal devices. It is in these areas that the Soviet's major problem lies, and not in the production of large central processors. The greatest area of Soviet interest, however, is in the smaller systems which are employed by the US at low organizational levels. This interest is not limited to tactical communications systems but also includes logistic control systems.[72] Such tactical communications and logistic control systems utilize fields of technology in which the Soviets have been unable to match Western accomplishments. These fields include miniaturization and the production of general purpose machines. These interests are well illustrated in the following quotations from a chapter written on Western accomplishments in the field of automation of troop control procedures.

> Modern computers of foreign armies have attained a high degree of miniaturization, a greatly increased capacity of accumulating systems, and a large-scale growth of the volume of information they can process.
>
> The basic path of the solution of this problem [troop control] lies in the introduciton of a complete complex of principally new technical means of control based on the accomplishments of radio-electronics. To be effective this must be done at the lowest possible levels... The development of such a system is the most long-range trend in the solution of troop control.[73]

The Soviets recognize the expanded capabilities that automation, computerization and use of cybernetic techniques afford the military commander. The increased scope and speed of actions allows for more centralization of decision making by permitting the commander to exercise more personal control over subordinate units at lower levels of organization.

TECHNOLOGY TRANSFER

The Soviet lag in technological development is a result of many causes, but chief among these is the early Soviet ideology. This ideology resulted in the myth that Russian science was always the best and most advanced in the entire world and all inventions and advances occur first in the Soviet Union. This led to a large amount of duplication of effort by the Soviets of work previously accomplished in the West.[74] This was coupled with the fact that Stalin disdained scientific accomplishment and thus the incentives for technological advancement were not present. After Stalin's death, the pressure of ideology on scientific and technological development gradually weakened, but the gap remained. As has been discussed above, one area in which this gap is felt is the Soviet computer industry. The Soviets recognize this gap exists and desire to eliminate it. One tactic of closing the gap rapidly has been through transfer of advanced technology from the West. If one accepts the premise that a gap in military technology provides a certain advantage to the more advanced nation, then it must also be accepted that maintenance of the gap is in that nation's best interest. Policy questions on technology transfer hinge on many issues besides military matters, such as economic and political considerations.[75] The questions are complex and sometimes it becomes difficult to segregate them into these sharply defined categories.

An adversary relationship between the United States and the Soviet Union was established during the "cold war" to the present. Because of this relationship direct transfer of arms is not a question nor is it contemplated. The transfer of other technology, such as computers, can have profound effects on the military capabilities of the Soviet Union, however, and must be closely scrutinized.

The first and most obvious question which must be addressed is how can the technology in question be applied to military matters. Where US policy is not to transfer technology for direct military application, knowledge can be gained that is applicable to military use even though the specific device transferred is used exclusively in the civilian sector. This is referred to as the "resource releasing effect".[76] The policy maker is faced with several questions which are difficult to answer. When does technology transfer make a "significant" contribution to the military potential of the recipient country? What is the acceptable risk when trading high technology to the Soviets? These questions must be asked every time any transfer of technology is contemplated.

Another question deals with third country transfers. This question has two sides. First, to what degree are we willing to permit further transfer of the technology by the recipient? Second, how are we able to insure that the technology is not given to a country we do not want to get it? Clauses written into transfer agreements can deter overt transfers but covert transfers are more difficult to combat. The more widely spread a technology, the more vulnerable it is to indirect leakage. This argument would tend to support the position that transfer of high technology to East European countries is contrary to US interests as they are the most likely to pass it on to the Soviet Union. This argument is sometimes countered with the viewpoint that by giving new technology to East-Bloc nations, the US is decreasing their dependence on the Soviet Union.[77]

Even if the US is virtually assured that a given system intended for transfer has no military application whatsoever, its transfer can still affect military capabilities. This is accomplished by result of releasing resources from civilian enterprises for use by the military.

The present embargo on technology transfer that has resulted from the Soviet invasion of Afghanistan could provide analysts an invaluable opportunity to evaluate the effects of technology transfer. If the embargo lasts long enough and the Soviets continue to make progress in technological development and close the gap more without US transfers, then it can be concluded that the economic and political considerations of technology transfer should take precedence in the future. On the other hand, if the Soviet industry suffers a setback, the argument for limiting high technology transfer gains credence.

CONCLUSIONS

Computer technology and cybernetic techniques used in military applications can have great impact on Soviet military doctrine and policy making. Computers are used to control the flights of airplanes, the trajectories of missiles and to automatically conduct bombing operations. They are also the most important element of the target acquisition and tracking elements of antiaircraft defense weapons. In the Navy, computers can again provide target acquisition and tracking services as well as serving as navigational aids. Computers are recognized by the Soviets as being essential to effective large-scale communications and information processing systems. This application aids immeasurably in the commander's decision-making process. Computers have also been given a great deal of attention in the field of training. Teaching machines and simulators are frequently mentioned in the Soviet press.

Computers and cybernetic techniques also aid the Soviets in testing new tactical concepts. Modeling has afforded them a means of evaluating new tactics to be used in modern battle without the benefit of an actual battlefield. The use of cybernetic techniques with or without the aid of computers is gaining in popularity in the Soviet military. These techniques are employed in planning military actions for the most effective utilization of personnel and equipment and reacting quickly to the ever-changing situation of the model battlefield. The major benefits of such application, as seen by the Soviet military leaders, are two-fold. First is increased combat efficiency and capability. Second is centralization of command and decision-making authority. The Soviets are ever stressing the overwhelming volume of combat information that a commander and staff are required to process and evaluate during the course of battle. The implementation of automation and cybernetic decision-making techniques frees the commander and his staff for other activities. This can be looked upon in another way, however. The use of these devices and techniques can be considered as a means of centralizing direction at a high level and providing machine solutions to problems and situations. This centralization may be a way of consolidating control rather than allowing lower-level leaders to exercise initiative.

The application of computers and cybernetics in the military can also carry with it some problems. The inherent nature of the Soviet system, especially when dealing with military matters, results in the fact that they do not publicly air these military shortcomings. As a result one must assume that the problems which are experienced and written about in the civilian sector are also found to some degree in military circles. This assumption must be tempered with the fact that the military tends to have preference over much of the civilian sector when it comes to resource allocation and also tends to assimilate technology better.[78] The shortcomings noted in the Soviet press are therefore worthy of consideration, especially the personnel and software problems. If one assumes that the shortage of trained personnel in the Soviet computer industry and civilian sector is also reflected in the military, the the introduction of computers and cybernetics into military organizations, without the necessary qualified personnel to use them can be an inefficient expenditure of money and effort, and at worst can cause utter chaos. The situation is analagous to building an automobile without wheels. The potential may be there, but it is wasted if it cannot be exploited. The problems are recognized by the Soviets but according to their own writings they have been extremely slow and ineffectual in dealing with them. An article appearing in Pravda in April 1979 cited problems which were addressed over ten years earlier.[79]

> As this all-important stage of development [of computers] takes place, attention must also be rendered to the acquisition of spare parts and [peripheral] instruments to insure that these computers don't just lay around like dead cargo.

The article also dealt with the need for standardization of software packages and the need for centralized production management and servicing.

Criticism of the Soviet computer industry in the Soviet press sharply decreased with the introduction of the Ryad Unified Computer System. This can be attributed to the fact that the problems which were receiving the greatest attention were greatly reduced by the Ryad. With the introduction of a unified system, standardization ceased to be a major problem. The problem of software has been reduced, partially because of the compatibility of th IBM 360 software and partially as a result of increased Soviet interest in software development. The Soviet Union purchased an IBM 360/40 and an IBM 360/50 in 1972 and an IBM 360/70 in 1976. These systems were accompanied by extensive software packages as is the custom with US computer systems.

Shortcomings discussed in the Soviet press are all basically related to methods and lack of emphasis in the proper fields. There is little or no mention of the technological shortcomings of the Soviet industry. This is not to say that they don't exist. It is in this area that the West enjoys its greatest advantage. The Soviet Union is 10 to 15 years behind in the field of general purpose digital computer design and production. In order to close this gap they are going to have to make giant strides in the areas of microelectronics, industrial quality control and data communication. The Soviets recognize these shortcomings, but seemingly have had difficulty in dealing with them effectively. The overwhelming indication is that the decisions of the 24th Party Congress in effect scrapped the Soviet computer industry and accepted the fact that they must copy the developments of the West. This seems to have resulted in the Soviets losing any initiative they may have had for independent technological developments in the field. As a result the question of technology transfer gains in importance.

This lead enjoyed by the West in technology is significant but must be tempered by the fact that the balance between quality and quantity is delicate. At some point a "law of diminishing returns" comes into effect regarding the utility of computer technology. How much is enough? The Soviets have substituted analog computers and employed older (obsolete by Western standards) digital machines for military use. But who is to say they can't get the job done? The United States cannot afford to feel too comfortable in its position. New advances must be constantly sought and the transfer of technology prevented if the United States is to maintain its advantage.

FOOTNOTES

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4. John R. Thomas and Ursala M. Kruse Vaucienne (eds.), Soviet Science and Technology--Domestic and Foreign Perspectives, (Washington: George Washington University, 1977), p. 190.

5. S. A. Majorov, "Vychyslitel'naya teknika i eye rol' v nardonom khozyaystve," Priborstroyenniye, No. 10, 1967, pp. 59-70, as translated by Irene M. Agnew for RAND Corporation, Soviet Cybernetics: Recent News Items, (No. 20, 1968), p. 6.

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9. V. Glushkov, et al, "O nekotorykh problemakh kibernetiki," Izvestiya, 6 September 1964, p. 4.

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15. A. Fomichev, "Vazhneysheye zveno," Tekhnika i vooruzheniye, No. 8, 1968, p. 37.

16. V. Glushkov, "Prodiktovano zhizn'yu," Pravda, 23 August 1969, p. 3.

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18. M. Ellen Jones, Cybernetics and Computers in Soviet Military Decision Making, Thesis (Delivered to the Ninth National Conference of the American Association for the Advancement of Slavic Studies, October 1978). p. 7.

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21. "Rychagi upravleniya," Pravda, 25 December 1969, p. 2.

22. B. Del Rio, "Kibernetika: k obshchemu znamenatel'ye," Pravda, 5 Janury 1971, p. 2.

23. Specifically mentioned is the Ural-14 system as having been delivered to users with less than the normal complement of core storage blocks or magnetic drums.

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47. Jones, p. 4.

48. Ibid., p. 7.

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50. V. G. Reznichenko, Tactics (The Officers Library), trnaslated by Foreign Technology Division, Defense Documentation Center, AD659928, 1967, pp. 39-40.

51. "Kibernetika i teoriya upravleniya voyskami," Krasnaya zvezda, 18 January 1968, p. 2.

52. "Chasovyye neba rodiny," Krasnaya zvezda, 23 July 1968, p. 1.

53. RAND Corporation, Soviet Cybernetic Review, Volume 4, April 1970, p. 46.

54. The M-220 is a second generation general purpose computer often employed for military purposes. General specifications are as follows:

Word length	45 (bits)
Immediate access storage capacity	4-16 (thousand words)
Access time to immediate access storage	6 (microseconds)
Mean time for execution of operations	
Addition	28 (microseconds)
Multiplication	53 (microseconds)

55. "Vychislitel'naya tekhnika i stroyki," Krasnaya zvezda, 20 August 1968, p. 2.

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